

NASA's Space Launch System: Deep-Space Opportunities for SmallSats

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Designed for human exploration missions into deep space, NASA's Space Launch System (SLS) represents a new spaceflight infrastructure asset, enabling a wide variety of unique utilization opportunities. While primarily focused on launching the large systems needed for crewed spaceflight beyond Earth orbit, SLS also offers a game-changing capability for the deployment of small satellites to deep-space destinations, beginning with its first flight. Currently, SLS is making rapid progress toward readiness for its first launch in two years, using the initial configuration of the vehicle, which is capable of delivering 70 metric tons (t) to Low Earth Orbit (LEO). On its first flight test of the Orion spacecraft around the moon, accompanying Orion on SLS will be small-satellite secondary payloads, which will deploy in cislunar space. The deployment berths are sized for "6U" CubeSats, and on EM-1 the spacecraft will be deployed into cislunar space following Orion separate from the SLS Interim Cryogenic Propulsion Stage. Payloads in 6U class will be limited to 14 kg maximum mass. Secondary payloads on EM-1 will be launched in the Orion Stage Adapter (OSA). Payload dispensers will be mounted on specially designed brackets, each attached to the interior wall of the OSA. For the EM-1 mission, a total of fourteen brackets will be installed, allowing for thirteen payload locations. The final location will be used for mounting an avionics unit, which will include a battery and sequencer for executing the mission deployment sequence. Following the launch of EM-1, deployments of the secondary payloads will commence after sufficient separation of the Orion spacecraft to the upper stage vehicle to minimize any possible contact of the deployed cubesats to Orion. Currently this is estimated to require approximately 4 hours. The allowed deployment window for the cubesats will be from the time the upper stage disposal maneuvers are complete to up to 10 days after launch. The upper stage will fly past the moon at a perigee of approximately 100km, and this closest approach will occur about 5 days after launch. The limiting factor for the latest deployment time is the available power in the sequencer system. Several NASA Mission Directorates were involved in the development of programs for the competition, selection, and development of EM-1 payloads that support directorate priorities. CubeSat payloads on EM-1 will include both NASA research experiments and spacecraft developed by industry, international and potentially academia partners. The Human Exploration and Operations Mission Directorate (HEOMD) Advanced Exploration Systems (AES) Division was allocated five payload opportunities on the EM-1 mission. Near Earth Asteroid (NEA) Scout is designed to rendezvous with and characterize a candidate NEA. A solar sail, an innovation the spacecraft will demonstrated for the CubeSat class, will provide propulsion. Lunar Flashlight will use a green propellant system and will search for potential ice deposits in the moon's permanently shadowed craters. BioSentinel is a yeast radiation biosensor, planned to measure the effects of space radiation on deoxyribonucleic acid (DNA). Lunar Icecube, a collaboration with Morehead State University, will prospect for water in ice, liquid, and vapor forms as well as other lunar volatiles from a low-perigee, highly inclined lunar orbit using a compact Infrared spectrometer. Skyfire, a partnership with Lockheed Martin, is a technology demonstration mission that will perform a lunar flyby, collecting spectroscopy, and thermography data to address questions related to surface characterization, remote sensing, and site selection. NASA's Space Technology Mission Directorate (STMD) was allocated three payload opportunities on the EM-1 mission. These slots will be filled via the

Centennial Challenges Program, NASA's flagship program for technology prize competitions, which directly engages the public, academia, and industry in open prize competitions to stimulate innovation. The NASA Science Mission Directorate (SMD) was allocated two payload opportunities on the EM-1 mission. The CubeSat Mission to Study Solar Particles (CuSP) payload will study the sources and acceleration mechanisms of solar and interplanetary particles in near-Earth orbit, support space weather research by determining proton radiation levels during Solar Energetic Particle (SEP) events and identifying suprathermal properties that could help predict geomagnetic storms. The LunaH-Map payload will help scientists understand the quantity of H-bearing materials in lunar cold traps (~10 km), determine the concentration of H-bearing materials with 1m depth, and constrain the vertical distribution of H-bearing materials. The final three payload opportunities for the EM-1 mission were allocated for NASA's international space agency counterparts. The flight opportunities are intended to benefit the international space agency and NASA as well as further the collective space exploration goals. ArgoMoon is sponsored by ESA/ASI and will fly along with the ICPS on its disposal trajectory to perform proximity operations with the ICPS post-disposal, take external imagery of engineering and historical significance, and perform an optical communications demonstration. EQUULEUS, sponsored by JAXA, will fly to a libration orbit around the Earth-Moon L2 point and demonstrate trajectory control techniques within the Sun-Earth-Moon region for the first time by a nano spacecraft. The mission will also contribute to the future human exploration scenario by understanding the radiation environment in geospace and deep space, characterizing the flux of impacting meteors on the far side of the moon, and demonstrating the future deep space exploration scenario using the "deep space port" at Lagrange points. OMOTENASHI, also sponsored by JAXA, will land the smallest lunar lander to date on the lunar surface to demonstrate the feasibility of the hardware for distributed cooperative exploration system. Small landers will enable multi-point exploration, which is complimentary with large-scale human exploration. Once on the lunar surface, the OMOTENASHI spacecraft will observe the radiation and soil environments of the lunar surface by active radiation measurements and soil shear measurements. Following EM-1, Space Launch System will evolve to the more-powerful Block 1B configuration, which uses a new Exploration Upper Stage to increase the vehicle's LEO payload capability from 70 t to 105 t. With that transition, the Orion Stage Adapter, which will carry the secondary payloads on EM-1, will be phased out, and a new Universal Stage Adapter will be introduced, creating opportunities for flying larger secondary payloads. This paper will provide a brief status of SLS progress toward first launch; an overview of smallsat accommodations, integration, and operations on EM-1; information about the specific payloads flying on that launch; and a discussion of future accommodations and opportunities for secondary payloads on SLS for Exploration Mission-2 and beyond.